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Impact of Palm Oil Mill Effluent (POME) on Soil Physico-Chemical Properties and Some Vegetative Parameters of Maize (*Zea mays* L.) Plant

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ABSTRACT: Indiscriminate disposal of palm oil mill effluent (POME) on land occurs in the palm oil – producing region of Nigeria. The aim of this study was to investigate the effects of POME on soil physico-chemical characteristics and the vegetative profile of maize plant. Fresh POME was used to pollute soil at 10%, 20% and 30% (w/w). Physico-chemical analysis of the soil used for planting was carried out before and at the end of the experiment. Vegetative analysis of the maize plants after 2, 3 and 4 weeks of planting revealed significant decrease ($P < 0.05$) in leaf area, stem height, root weight and chlorophyll number in the plants grown in POME-treated soil compared to control. Analysis of soil samples at the end of the study showed an increase in soil sodium, potassium, magnesium, electrical conductivity and cation exchange capacity with increasing application of POME. Percentage carbon, nitrogen and organic matter in POME – treated soils when compared to control post-planting were found to be decreased. However the highest values were obtained in the 30% POME - treated group. Phosphorus levels in the POME - treated soils were observed to be sharply reduced when compared to the control soil. No variation in the levels of aluminium ions in the POME-treated groups was observed post-planting. The authors infer that despite the increased availability of some plant nutrients in the soil, the reduced values obtained for vegetative parameters suggest that POME may not be beneficial for plant growth at the concentrations studied.

Keywords: maize, soil, POME, chlorophyll number, vegetative parameters

Introduction

The oil palm plant (*Elaeis guineensis*) is native to many West African countries where the locals use its oil mainly for culinary purposes. It is one of the most widely used cooking oils in West and Central Africa (1, 2).
A lot of water is used in the palm oil extraction process. About half of the water is lost as steam while the other half results in palm oil mill effluent (POME). POME is a high volume liquid waste which is non-toxic, organic in nature with an unpleasant odour and is highly polluting (3). About 2.5 tonnes of this waste is produced for every tonne of oil extracted from an oil mill (4). POME consists of about 94% water; it is mainly the sum total of liquid waste which cannot be easily or immediately reprocessed for extraction of useful products and is run down the mill internal drain system (5).
POME, as most other agro-industrial effluents is a serious nuisance when discharged untreated as it contains high levels of organic load and some organic acids. The phytotoxic properties of this effluent can be attributed to the high concentrations of polyphenols, which possess antibacterial properties. In developing countries such as Nigeria, this effluent is often discharged on agricultural land as a cost-saving strategy[6]. Discharging of POME on land may lead to pollution and might deteriorate the surrounding environment (7).
There is the indication of alteration of soil properties such as cation exchange capacity following the application of POME to soil (8). POME contains appreciable amounts of nitrogen, phosphorus, potassium, magnesium and calcium, which are the vital nutrient elements for plant growth. It may thus be used as fertilizer or animal feed under appropriate conditions[7]. Growth inhibition in different plants after POME application to soil has also been observed (9).
The present study investigated the effect of POME on soil physico-chemical properties and vegetative parameters of maize (*Zea mays*) grown on soil polluted with POME.

Materials and Methods

Maize seeds (*Zea mays*) were purchased from Uselu Market in Benin-City, Edo State, Nigeria. The soil sample used for planting was obtained from a farmland in Oluku Junction in Benin-City. The palm oil mill effluent (POME) was obtained from the Nigerian Institute for Oil Palm Research (NIFOR), Km 7 along Benin-Akure Road, Benin-City, Edo State, Nigeria.
Three (3.0) kilograms of soil was weighed into each polythene bag. Six (6) bags were labelled as control, with nothing added to them. Three (3) other groups consisting of six bags of soil each were treated with 10%, 20% and 30% POME (w/w).
Five viable maize seeds, selected by simple flotation method were planted, evenly spaced, in each bag. The bags were transferred to the greenhouse to simulate an almost natural environment. Each bag was moistened daily with 50ml of water. After germination, vegetative measurements of seedlings were carried out at the end of each week for four weeks.
Leaf area was determined according to the method of Montgomery[10]. The entire leaf length was multiplied by the broadest portion of the width and with a factor (0.75). The stem height was determined by measuring the length of the plant stem from the stem origin at the base of the soil to the terminal node. The roots of harvested plants were washed with distilled water to remove sand particles and root weight carried out using a laboratory weighing balance. Chlorophyll number was determined according to the method of Dere *et al* [11] with acetone as solvent. Calculation of chlorophyll a and chlorophyll b amounts, and hence chlorophyll number was done using

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the formula of Lichtentaler and Wellburn (12). Soil pH was determined according to the method of Folson *et al* (13). Electrical conductivity was determined using a calibrated conductivity meter with the sample prepared as described for pH determination. Organic carbon was carried out using the modified method of Walkey-Black rapid dichromate oxidation technique (14). Exchangeable cations were determined according to the method of Jackson (15). The Bouyoucos hydrometer method (16) was used to determine particle size. Nitrogen was determined by the micro kjeldahl method as described by Jackson (15). Available phosphorus was determined using the method of Bray and Kurtz (17).
The results were expressed as mean ± SEM. Analysis of variance (ANOVA) was used to test for differences in the groups. A P value of 0.05 was set as the level of significance.

Results

Table 1: Physico-chemical properties of Palm oil mill effluent obtained from NIFOR, Benin-City

Parameter	Value
P^H	4.85
Electrical Conductivity (µs/cm)	382.00
Nirogen (mg/L)	3094.44
Phosphorus (mg/L)	1483.87
Total Soluble Solids (mg/L)	11000.00
Calcium (mg/L)	145.89
Magnesium (mg/L)	46.67
Sodium (mg/L)	629.00
Potassium (mg/L)	6477.00
Total Dissolved Solids (mg/L)	349.00

This table shows the physico-chemical properties of raw POME. The POME is acidic with high concentrations of dissolved and soluble solids as well as mineral elements.

Table 2: Physico-chemical properties of soil samples before the experiment and at the end of the experiment

	Soil (pre planting)	Soil (After planting)			
	Control	Control	10% POME	20% POME	30% POME
P^H	5.9	4.8	5.3	5.3	5.4
Electrical conductivity (µS/cm)	273	44.4	38.6	93.4	93.3
% Nitrogen	0.195	0.213	0.197	0.174	0.213
% Carbon	2.88	3.232	2.272	2.176	2.752
% Organic matter	5.98	5.588	3.928	3.762	4.758
Phosphorus (ppm)	21.11	16.115	2.031	3.608	2.753
Calcium (mEq/100g soil)	3.84	3.84	3.28	3.36	4.64
Magnesium (mEq/100g soil)	1.17	1.12	2.16	2.00	3.12
Sodium (mEq/100g soil)	0.38	0.285	0.293	0.293	0.301
Potassium (mEq/100g soil)	0.2	0.201	0.321	0.602	0.647
Hydrogen ions	0.2	2.5	0.9	0.8	0.9
Aluminium (mEq/100g soil)	N.D	1.10	0.20	0.20	0.20
Cation exchange capacity	5.791	5.046	7.154	7.255	9.808
% Clay	2.6	2.3	2.3	2.3	2.3
% Silt	4.7	7.8	5.8	5.3	5.3
% Sand	92.7	89.9	91.9	92.4	92.4

**N.D = not detected*

Table 2 above shows the physico-chemical properties of soil samples before the experiment and at the end of the experiment.
The soil pH was generally found to be acidic in all the treatments. The results show increase in soil magnesium, sodium and potassium upon the addition of POME to these soils. The increase was greatest in the soils with 30% (w/w) POME application. Electrical conductivity and cation exchange capacity also increased in the POME-treated soils. A sharp decrease in available phosphorus in the POME treated soils was observed compared to the control soil.

Table 3: Leaf area (cm^2) of maize grown in different concentrations of palm oil mill effluent polluted soil.

	Week 1	Week 2	Week 3	Week 4
Control	24.40 ± 0.93^a	51.02 ± 2.84^a	73.16 ± 6.10^a	74.43 ± 2.71^a
10% POME pollution	20.72 ± 0.94^b	43.68 ± 0.99^b	55.84 ± 0.98^b	64.00 ± 5.74^b
20% POME pollution	20.86 ± 1.09^b	36.29 ± 1.67^c	37.17 ± 0.69^c	42.50 ± 2.94^c
30% POME pollution	20.72 ± 0.95^b	34.17 ± 1.56^c	37.08 ± 3.48^c	38.10 ± 3.13^d

Values represent mean ±SEM (in cm^2).

The various alphabets in the table indicate significant differences. Similar alphabets reflect no significant difference (P > 0.05) between the values while different alphabets reflect significant differences (P< 0.05) between the values.
Significant reduction in leaf area between control and the POME treatments was observed in all weeks. In the first week, there was no significant difference between the various POME treatment groups. For weeks 2 and 3, significant differences between the 10% POME – treated group and the 20% and 30% POME-treated groups was observed. There was no significant difference between the 20% and 30% POME-treated groups. At week 4 significant differences was observed between all the POME treatment groups, with leaf area decreasing as POME application increased.

Table 4: Stem height (cm) of maize plants grown in different concentrations of palm oil mill effluent polluted soil.

	Week 1	Week 2	Week 3	Week 4
Control	6.78 ± 0.17^a	11.71 ± 0.35^a	15.16 ± 0.55^a	15.67 ± 0.48^a
10% POME pollution	6.61 ± 0.18^a	9.81 ± 0.14^b	12.75 ± 0.64^b	13.92 ± 0.65^a
20% POME pollution	6.45 ± 0.20^a	8.18 ± 0.19^c	11.64 ± 0.46^b	12.67 ± 0.84^b
30% POME pollution	6.23 ± 0.16^b	8.27 ± 0.19^c	9.95 ± 0.65^c	11.20 ± 0.34^b

Values represent mean ± SEM (in cm).

The various alphabets in the table indicate significant differences. Similar alphabets reflect no significant difference (P > 0.05) between the values while different alphabets reflect significant differences (P< 0.05) between the values.
Stem height of *Zea mays* plants showed no significant difference (P > 0.05) between the control, 10% and 20% POME pollution in the first week. A significant difference (P < 0.05) between the control and 30% POME pollution was however observed. Significant decrease in the stem heights however occurred between the control and the various treatments for weeks 2 – 4.

Table 5: Root weight (gm) of maize grown in different concentrations of palm oil mill effluent polluted soil.

	Week 2	Week 3	Week 4
Control	1.67 ± 0.12^a	1.86 ± 0.04^a	1.96 ± 0.15^a
10% POME pollution	1.84 ± 0.02^b	1.91 ± 0.17^b	2.29 ± 0.10^a
20% POME pollution	1.15 ± 0.15^c	1.33 ± 0.20^c	1.61 ± 0.13^b
30% POME pollution	0.67 ± 0.01^d	0.78 ± 0.07^c	0.95 ± 0.07^c

Values represent mean ± SEM (in grams).

The various alphabets in the table indicate significant differences. Similar alphabets reflect no significant difference (P > 0.05) between the values while different alphabets reflect significant differences (P< 0.05) between the values.
There was significant difference (P < 0.05) in the weight of *Zea mays* roots between the control and the treatments at weeks 2 – 4. Significant reduction in root weight was observed as POME contamination increased.

Table 6: Chlorophyll number of maize leaves grown in different concentrations of palm oil mill effluent polluted soil.

	Week 2	Week 3	Week 4
Control	31.29 ± 1.47^a	32.88 ± 1.03^a	40.72 ± 0.92^a
10% POME pollution	31.26 ± 0.60^a	27.83 ± 0.94^b	30.59 ± 1.15^b
20% POME pollution	30.58 ± 0.97^a	24.56 ± 1.33^b	29.39 ± 0.67^b
30% POME pollution	31.41 ± 0.73^a	25.64 ± 1.77^b	27.59 ± 2.51^b

Values represent mean ± SEM (in µg/g fresh leaf).

The various alphabets in the table indicate significant differences. Similar alphabets reflect no significant difference (P > 0.05) between the values while different alphabets reflect significant differences (P< 0.05) between the values.
No significant difference (P > 0.05) in chlorophyll number was observed between groups at week 2. There was however significant difference (P< 0.05) between the control and treatments at weeks 3 and 4. Reduction in chlorophyll number as POME pollution increased was observed. This was however not significant between the pollution groups.

Discussion

Palm oil is processed locally and industrially through the oil palm belt stretching from Lagos to Cross River in Nigeria (18). During this process, palm oil mill effluent (POME) is produced in very large quantities (19).
The locations of many small scale private palm plantations where palm oil mill processing take place in Nigeria increases the problem of indiscriminate discharge of raw, untreated POME on agricultural land or water bodies. As stated by Awotoye *et al.* (20), this mindless abuse of our environment by indiscriminate discharge of effluent is unhealthy and discouraged in developed countries where industries are encouraged to strive towards cleaner technologies that do not impact negatively on the environment.
The results of soil analysis post-experiment show increase in soil Na, K, Mg, electrical conductivity and cation exchange capacity with increasing application of POME. Soil pH remained acidic at all levels of POME application. This is in agreement with Nwoko and Ogunyemi (21) and Osaigbovo and Orhue (9). Lopez *et al.* (23) suggested that this increase may be attributable to the acidic nature of POME.

A sharp decrease in soil phosphorus in soils treated with POME was observed. This is not in agreement with Nwaugo *et al*. (23) and Iwara *et al*. (24). However, this difference may arise due to the fact that these researchers allowed the POME to ferment in the soil for varying lengths of time before planting. The time of incubation may therefore enhance the availability of phosphorus in the soil.

Vegetative parameters such as leaf area and stem height were observed to be significantly ($P < 0.05$) higher in the control group compared to those grown in POME-treated soils. This agrees with the observations of Osaigbovo and Orhue (9) who suggested that the poor growth parameters in POME treated soils despite increase in soil minerals may be due to reduced uptake of these plant nutrients. The oily nature of the POME may inhibit nutrient uptake by creating anaerobic conditions in the soil.

Plant roots are the sites for uptake of nutrients from the rhizosphere. Significant decrease ($P < 0.05$) in root weight in the POME treated soils compared to control may further account for reduced nutrient uptake and hence, poorer vegetative parameters.

Chlorophyll is vital for photosynthesis and its distribution within maize leaves is in general homogeneous at a specific growth stage. However, stress in a plant may result in both a loss of chlorophyll and a change in its distribution pattern (25). This is seen in the chlorophyll number as determined. A significant decrease ($P < 0.05$) in the chlorophyll number of maize grown in the POME treated soil is observed, suggesting that POME induces stress in the plants.

There have been reports of POME being beneficial to maize growth (19, 26). They however point out that the usefulness of POME may depend on the amount applied to soil, the duration of application prior to planting and the fermentation of POME for varying lengths of time before application to soil.

This study has demonstrated that POME, at the concentrations studied, negatively affected the vegetative parameters of maize (*Zea mays*) grown in soils polluted with POME. This suggests that POME may not be beneficial for direct soil application. Further research however needs to be carried out to ascertain if under any set of conditions, POME may be beneficial to crop growth.

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